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AUTHOR Kohen, Eileen
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ABSTRACT

The purpose of the present study was to norm and validate the College-Level Examination Program (CLEP) Introductory Calculus Subject Examination for two University of Illinois calculus courses, Math 120 and Math 135. It was of interest to determine if this examination could be used as a calculus placement and proficiency examination for new students who have a background of at least one semester of calculus, and who received high scores on the College Entrance Examination Board (CEEB) Advanced Mathematics Placement Test. CLEP Calculus scores did differentiate between students who performed at different grade levels within both Math 120 and Math 135. Validity and KR-21 reliability coefficients were quite high. A cutoff score based on the score at which no student received a D or E grade was recommended for granting proficiency for Math 120. Although a cutoff score was suggested for Math 135 proficiency, validity data for higher level calculus courses was recommended. (Author)

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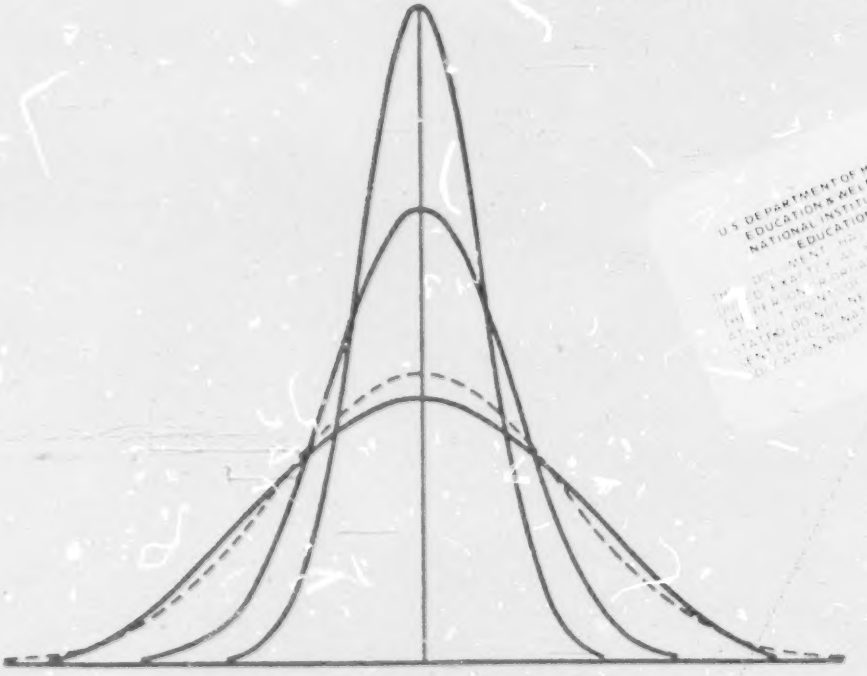
Research Report

TITLE

A VALIDITY STUDY FOR THE CLEP INTRODUCTORY CALCULUS SUBJECT EXAMINATION AT THE UNIVERSITY OF ILLINOIS

AUTHOR(S)

Eileen Kohen



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MEASUREMENT AND RESEARCH DIVISION - OFFICE OF INSTRUCTIONAL RESOURCES
307 ENGINEERING HALL - UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS 61801

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A VALIDITY STUDY FOR THE CLEP INTRODUCTORY CALCULUS SUBJECT EXAMINATION AT THE UNIVERSITY OF ILLINOIS

Introduction

Recently there has been a growing interest in developing test instruments for placing students into appropriate college level courses and/or assigning them proficiency credit. Placement and proficiency (P/P) examinations become increasingly more relevant when a university wishes to establish "time-shortened degrees" in which a student can complete the requirements for a baccalaureate degree in less than the traditional four years.

P/P examinations have been used for several years at the University of Illinois (see Stallings, Aleamoni, and Heil, 1972). The Mathematics Department currently uses the CEEB Intermediate and Advanced Mathematics Placement tests to place incoming students into all mathematics courses. The amount of mathematics background determines which examination a student takes. If the student has taken a trigonometry course and at least three and one-half years of high school mathematics, he is administered the Advanced Mathematics Examination. Otherwise, he takes the Intermediate Mathematics Examination. Students who want to take any calculus courses now take the Advanced Mathematics Test; placement is contingent on their Advanced Mathematics score and their background in analytical geometry. Students with an Advanced Mathematics formula score above 25 are placed into Math 135 if they have completed at least one semester of high school analytic geometry, or into Math 120 if they have not. Math 120 and Math 135 both are introductory calculus courses. Math 120 is the first course in the Math 120-130-140 sequence or the Math 120-131-141 sequence; Math 135 is the first course in the Math 135-145 sequence. The same calculus material is included in

both sequences, however, analytic geometry is omitted from Math 135-145. Analytic geometry is presented throughout the Math 120-130-140 sequence as a means toward understanding the calculus material.

The Mathematics Department has expressed an interest in utilizing a mathematics proficiency test with high content validity in calculus. They prefer not to base proficiency decisions on the results of the CEEB Advanced Mathematics Examination, consisting of college algebra, plane geometry, and trigonometry problems. These test items have little or no relationship to the actual calculus course content. Instead, students who score high on the Advanced Mathematics Examination, *and* who have taken at least one semester of calculus should be eligible to take a calculus P/P examination. One likely choice for this examination is the CLEP Introductory Calculus Subject Examination. The items in this examination specifically test knowledge and assimilation of calculus subject matter.

The main purpose of the present study was to norm and validate the CLEP Calculus Examination for two calculus courses at the University of Illinois, Math 120 and Math 135. Local normative data is essential for determining valid and appropriate cutoff scores for placement into calculus courses and for proficiency credit. It is also of interest to compare the performance of University of Illinois students with the national CLEP norms generated by Educational Testing Service (ETS).

The predictive validity of the CLEP Calculus Examination for the local population depends on the answers to two questions:

1. Do the CLEP Calculus Examination scores adequately differentiate between the poor and good students within each calculus course?
2. Is there a significant difference between the mean scores of the different calculus courses into which students place?

Method

The CLEP Calculus Examination, Form MCT, was administered during final examination week to students in five sections of Math 120 (N = 94), and four sections of Math 135 (N = 81), fall semester, 1971. The students were informed that their final course grade would be partially based on their performance on the CLEP examination.

Examination scores based on the total 60 test items were computed for every student. In addition, the Mathematics Department selected 48 items with content relevance for Math 120 and 52 items for Math 135. Scores based only on these items were computed. The following variables also were available for each student:

1. *ACT Math Score:* predictor used for selecting students for admission at the University of Illinois.
2. *SCAT Quantitative Score:* subscore computed from SCAT which is administered after college admission for guidance purposes.
3. *P/P Advanced Math Score:* score currently used for placement into several mathematics courses.
4. *Math 120 or Math 135 final course grade:* end of course grade which was slightly influenced by the CLEP Calculus Examination score given as part of the final examination.

Results and Discussion

Table 1 shows a summary of statistics for Math 120 and Math 135 CLEP Calculus results. Table 1 includes results for the overall score distribution of 60 items, the overall score distribution omitting content irrelevant items, plus the score distribution of 60 items by final grade received in the course. The scoring formula used is the number of correct answers minus one-fourth of the number of incorrect answers (R-1/4W).

Table 1

Summary of Statistics

CLEP Introductory Calculus Examination

Test Statistics	Total Exam	Exam With Omits	Total Exam by Course Grade				
			A	B	C	D	E
Math 135							
Number of Items	60	52	60	60	60	60	60
Mean	19.75	18.74	27.90	21.00	17.28	13.86	9.56
Median	18.25	17.69	29.00	21.00	17.00	14.00	9.25
CLEP Mean Scaled Score	50.8	49.7	59.9	52.0	48.3	43.9	39.6
CLEP Mean Percentile Rank	55%	51%	84%	62%	45%	31%	15%
Standard Deviation	8.18	7.86	7.52	6.29	4.80	2.79	4.39
Range of Scores	4 to 45	4 to 38	16 to 45	11 to 34	8 to 28	10 to 18	4 to 15
Sample Size	81	81	21	19	25	7	9
Math 120							
Number of Items	60	48	60	60	60	60	60
Mean	14.09	13.57	21.50	17.07	10.41	5.31	.50
Median	13.77	13.38	21.50	17.00	11.00	6.50	-.50
CLEP Mean Scaled Score	44.1	43.6	52.5	48.1	40.4	34.3	28.5
CLEP Mean Percentile Rank	31%	31%	62%	45%	15%	5%	1%
Standard Deviation	7.61	7.31	5.38	5.20	4.50	3.94	5.20
Range of Scores	-3 to 31	-3 to 30	12 to 31	8 to 27	0 to 20	0 to 10	-3 to 8
Sample Size	94	94	22	27	32	8	4

The CLEP mean scaled score is derived from a distribution ranging from 20 to 80 with a mean of 50 and a standard deviation of 10. The CLEP mean percentile rank, corresponding to the mean scaled score, is based on ETS' national normative data for testing administrations on 483 students in spring 1964. These norms are based on students who have completed one year of calculus course work.

Local Normative CLEP Results. The overall CLEP mean score for Math 135 was significantly higher than that for Math 120 ($t = 4.74$, $df = 174$, $p < .001$). If the CLEP Calculus Examination is valid, then this result is to be expected because the students enrolled in Math 135 previously have completed the prerequisite of analytic geometry. The students in Math 120 are taught both analytic geometry and calculus; therefore, they cannot cover the same amount of calculus course material.

ETS reported the reliability of the CLEP Calculus Examination as measured by the Kuder-Richardson Formula 20 adjusted for use with formula scores (R-1/4W) at .83 (CLEP Score Interpretation Guide, p. 31). The reliability for the local University of Illinois sample measured by the Kuder-Richardson Formula 21 is almost identical to that of the ETS national sample. The Math 120 scores produced a KR-21 reliability of .82; the Math 135 scores produced a KR-21 reliability of .83. Note that the KR-21 Formula gives a lower bound estimate of reliability than KR-20.

There is a positive relationship between mean score and course grade. For both Math 120 and Math 135, the higher the final course grade, the higher the mean score. This is graphically illustrated in Tables 2 and 3. Table 2 shows the frequency of CLEP scores by course and final grade. Table 3 illustrates the mean, standard deviation, the range for Math 120 and Math 135 for

Table 2

Distribution of Course Grades Against CLEP Scores

CLEP Raw Score	CLEP Scaled Score	Math 120						Math 135					
		A	B	C	D	E	Total	A	B	C	D	E	Total
-3	25					2	2						
-2	26												
-1	27												
0	28			1	2	1	4						
1	30												
2	31				1		1						
3	32			2			2						
4	33			1			1					2	2
5	34			1			1						
6	35			1	1		2					1	1
7	36			3	2		5						
8	37		2			1	3			1			1
9	39		1	2	1		4					2	2
10	40			4	1		5			1	1	1	3
11	41		1	2			3		1	1	1		3
12	42	1		3			4			3			3
13	43	1	1	5			7		2		1		3
14	44		7	4			11				1	1	2
15	45	1	2	1			4		2	1	1	2	6
16	46							1		4	1		6
17	48	2	1				3		1	3			4
18	49	3	1				4	3	1	1	1		6
19	50	2	3	1			6		1	2			3
20	51	1	1	1			3		1	1			2
21	52		2				2		1	2			3
22	53	1	1				2	1	1	2			4
23	54	2	1				3	2	1	1			4
24	56		3				3	1	2	1			4
25	57	1					1		1				1
26	58	2					2		1				1
27	59	3	1				4						
28	60							1	1	1			3
29	61							3					3
30	62	1					1	2					2
31	63	1					1	1	1				2
32	65							2					2
33	66							1					1
34	67								1				1
35	68							1					1
36	69												
37	70												
38	71												
39	72												
40	74												
41	75							1					1
42	76												
43	77												
44	78												
45	79							1					1

Table 3

Graphic Representation of CLEP Calculus Results

Math 120

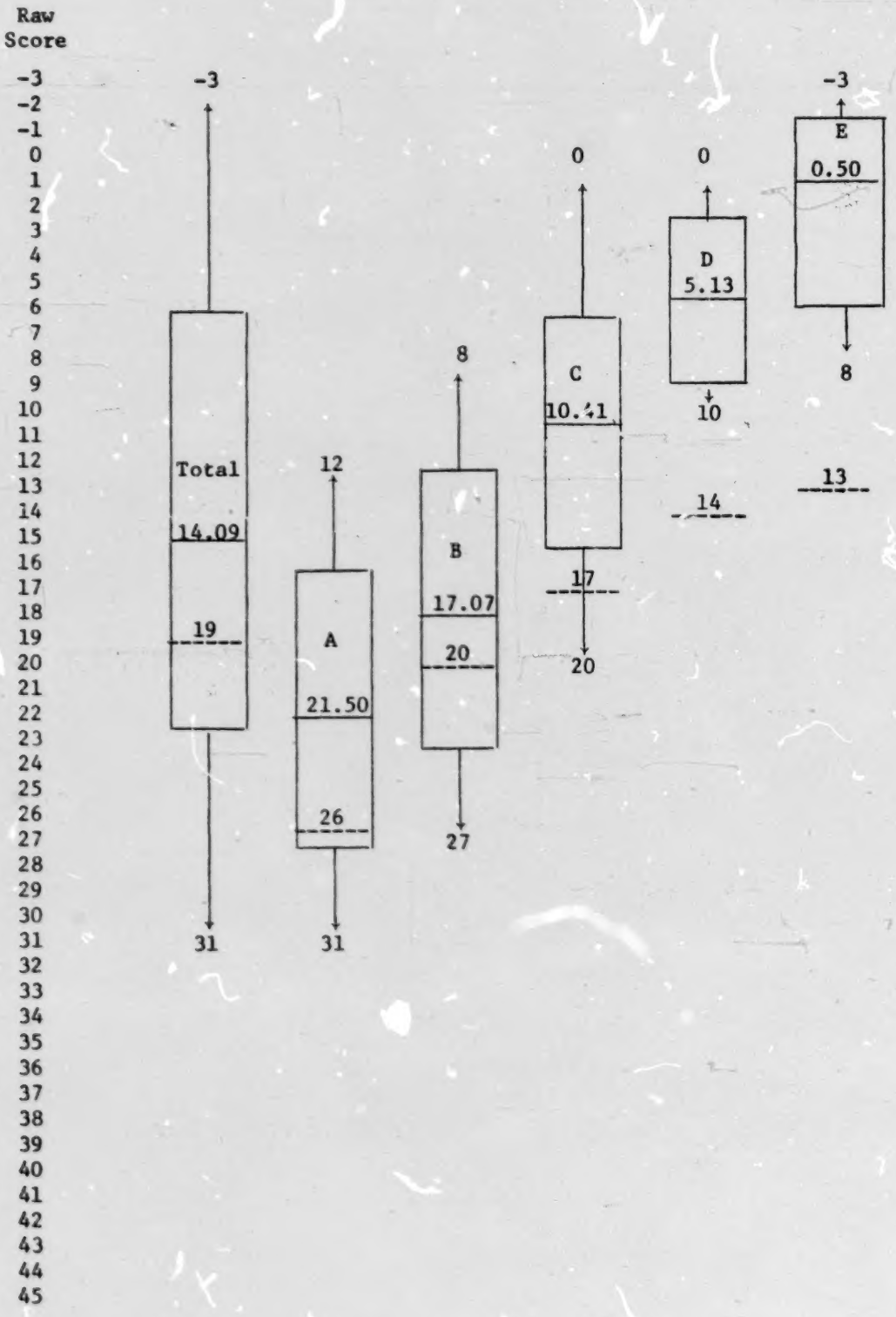
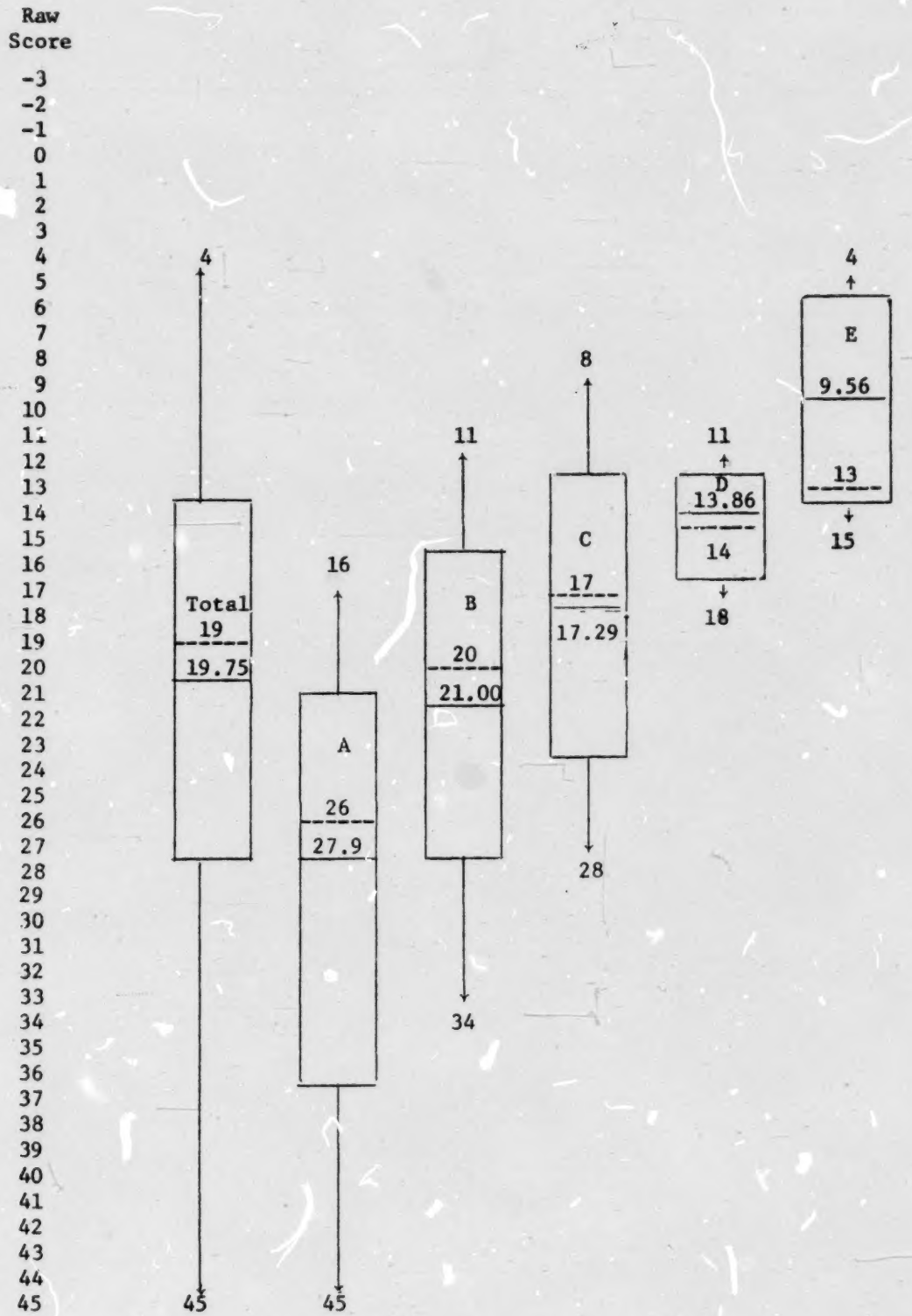


Table 3 (con't.)

Graphic Representation of CLEP Calculus Results

Math 135



the overall distribution and for the course breakdown. The mean sample raw score is indicated by the solid line within each rectangle. The mean raw score for the ETS national norms is shown by the broken line. The standard deviation is the score distance from the sample mean to the end of the rectangle. The range is indicated by the scores at the end of the arrows for each rectangle.

Tables 2 and 3 indicate that the CLEP scores can differentiate between students who perform at different grade levels within a course. Math 120 and Math 135 students within a particular grade level usually score lower than the mean score of the next higher grade level. Additionally, all of the scores for students earning a D or E in both Math 120 and Math 135 fall below the total mean CLEP scores.

Before deciding to accept an examination for P/P purposes, it is wise to examine its relationships with other possible instruments. Table 4 presents the means, standard deviations and intercorrelations of several quantitative examinations and the course grades in Math 120 and Math 135. It is interesting to note the exceptionally high correlation of .98 for both Math 120 and Math 135 between the CLEP Calculus Examination scored only with course relevant items (CLEP Calculus-Omits), and the CLEP examination scored with all 60 items (CLEP Calculus-Total). The pattern of correlations for these two CLEP measures with all other variables is practically identical for both Math 120 and Math 135. The scoring key with omitted items was generated in order to compute the Math 120 and Math 135 final examination grades only with items that related specifically to the course content. It was hypothesized that content validity would improve only if course related items were included in the examination. This hypothesis was not supported.

Table 4

Correlation Matrix of Relevant Variables

Variable	No.	Correlations 1	2	3	4	5	6	Mean	S. D.
Math 120 (N = 69 to 90)									
ACT Math	1	1.00						29.8	3.42
SCAT Quantitative	2	.78***	1.00					34.8	6.37
CLEP Calculus-Total	3	.22*	.26*	1.00				14.6	7.41
CLEP Calculus-Omits	4	.24*	.25*	.98***	1.00			14.2	7.17
P/P Advanced Math	5	.40***	.40***	.49***	.47***	1.00		20.4	6.48
Math 120 Course Grade	6	.20*	.21*	.78***	.78***	.48***	1.00	3.63	1.09
Math 135 (N = 69 to 78)									
ACT Math	1	1.00						31.0	4.38
SCAT Quantitative	2	.86***	1.00					38.0	7.68
CLEP Calculus-Total	3	.27*	.36**	1.00				19.0	8.07
CLEP Calculus-Omits	4	.26*	.35**	.98***	1.00			18.0	7.63
P/P Advanced Math	5	.29**	.43***	.44***	.46***	1.00		29.1	4.88
Math 135 Course Grade	6	.15	.26*	.70***	.73***	.35**	1.00	3.39	1.30

* $p < .05$

** $p < .01$

*** $p < .0005$

It is quickly noted that *all* intercorrelations among the quantitative examinations are positive and significant for both courses. This is an expected finding because all of these measures tap an underlying quantitative dimension. However, the similar pattern of intercorrelational values for both Math 120 and Math 135 bears further discussion. The highest correlation occurs between ACT Math and SCAT Quantitative. These both measure global quantitative aptitudes. In contrast the CLEP Calculus Examination and the P/P Advanced Mathematics Examinations both measure achievement, i.e., the questions primarily deal with solving specific algebra, geometry, trigonometry, or calculus problems. Interestingly, the intercorrelations of the aptitude measures are high and the intercorrelation of the achievement measures are high. However, the correlations of the aptitude versus achievement variables are lower than all other correlations.

The CLEP validity coefficients, i.e., correlations of course grades and CLEP scores, are very promising. For both Math 120 and Math 135, the correlations between course grade and ACT Math or SCAT Quantitative are fairly low. The validity coefficients for P/P Advanced Mathematics are much higher than for the aptitude measures. However, the validity coefficients for the CLEP Calculus Examination are higher than any others. Unfortunately, the CLEP validity coefficients are slightly inflated; the students' final grades were partially based on their CLEP scores. Although the degree of this spurious validity coefficient is very slight, it is important that the influence of CLEP scores are partialed out of the grades. No complete record of the exact influence of CLEP scores on each student's grade was kept; therefore, it cannot be accurately determined from the available data.

University of Illinois policy indicates that students who demonstrate course mastery at the C grade level by means of a P/P examination should be granted proficiency and/or be placed out of a course. If this premise is accepted, then two basic cutoff placement schemes can be derived. A student can be placed out of a course if he scores at or above: (1) the mean CLEP scaled score for that particular course; or (2) the CLEP scaled score at which no student received a D or E grade.

The CLEP scaled score distribution for Math 120 has a mean of 44.09; the scaled score above which no one received a D or E is 41. The CLEP scaled score distribution for Math 135 has a mean of 51; the scaled score above which no one received a D or E is 50. These scaled scores may be used as possible cutoff scores for placement and/or proficiency for Math 120 and Math 135. Table 5 presents a suggested calculus P/P schema. A student must receive a high score on the CEEB Advanced Mathematics Placement Test plus indicate the completion of at least one semester of calculus before he would be eligible to take the CLEP Calculus Examination. Then his placement and proficiency would be based on his performance on the CLEP Calculus Examination.

The present results strongly support the use of the CLEP Calculus Examination for Math 120 proficiency and Math 130 placement. However, this study's lack of validity data on the CLEP Calculus Examination for Math 145 makes any Math 135 proficiency and Math 145 placement rather tenuous. In a similar study for University of Illinois engineering students, Feldman and Kane (1973) reported that the CLEP Calculus Examination can indicate performance in introductory calculus courses but probably is not an appropriate measure of proficiency for math courses beyond Math 130. Little improvement was shown between pre and post-test results for Math 141. However, the Math

Table 5

Suggested Calculus Placement and Proficiency Schema

CLEP Calculus Formula Score (R-1/4S)	CLEP Scaled Score	Placement	Proficiency
-15 to 10	20 to 40	Math 120	None
11 to 60	41 to 80	Math 130 or 131	Math 120 (5 cr.)

141 results must be interpreted cautiously because its sample size was very small (N = 7). If there is interest in using the CLEP Calculus Examination in the P/P schema for higher level calculus courses, more empirical evidence is needed. A study similar to Feldman and Kane's could be run on Math 140, 141, or 145 classes with a larger sample size and a representative selection of students enrolled in the courses from all colleges.

Comparisons between local and national norms. Tables 1 and 3 include comparisons between local and national norms. As already indicated, the national norms are based on students who completed one complete year of calculus course work, while the present local norms are based on students only completing their first semester of calculus. Therefore, it is difficult to directly compare the local results with the national norms. There is evidence that the University of Illinois is academically superior to many of the colleges and universities included in the national sample (see Appendix B of the CLEP Score Interpretation Guide for a complete list of participating institutions). Kohen and Gillmore (1973) reported that University of Illinois beginning freshmen performed better than end-of-sophomore year students in the ETS national norming sample for three CLEP General Examinations (see Tables 6 to 9). However, the local CLEP Calculus mean scores are not superior to the national mean scores. The Math 135 results very closely match the national mean scores, both overall and by course grade breakdown (see Table 3). The national mean scaled score is established at 50.0; the local Math 135 overall mean scaled score is 50.9. In contrast, the Math 120 mean scaled score of 44.1 is below the national average, and the mean scores by course breakdown all fall far below the corresponding national mean scores. Based upon related data, if the University of Illinois sample received the same amount of course instruction as the national sample, the University of Illinois norms should be superior to the national norms.

Table 6

CLEP Natural Science Exam

Biological Science Subscore Norms

University of Illinois

ETS Standard Score	Formula Score		Percentile U. of I. LAS (1972) (N = 2789)	Approximate Percentile National Norms
	NCT1	NCT2		
72	44	47	99	99
71	43	46	99	98
70	42	45	98	98
69	41	44	97	97
68	40	43	96	96
67	39	42	94	95
66	38	41	91	95
65	37	40	88	93
64	36	39	86	92
63	35	38	83	90
62	34	37	80	88
61	33	36	76	86
60	32	35	72	84
59	31	34	68	82
58	30	33	63	79
57	29	32	60	76
56	28	31	56	73
55	27	30	51	69
54	26	29	48	66
53	25	28	45	62
52	24	27	41	58
51	23	26	37	54
50	22	25	34	50
49	21	24	31	46

Table 7

CLEP Natural Science Exam

Physical Science Subscore Norms

University of Illinois

ETS Standard Score	Formula Score		Percentile U. of I. LAS (1972) (N = 2780)	Approximate Percentile National Norms
	NCT1	NCT2		
77	48	47	99	99
76	47	46	98	99
75	46	45	98	99
74	45	44	97	99
73	44	43	97	99
72	43	42	96	99
71	42	41	94	99
70	41	40	93	97
69	40	39	92	96
68	39	38	90	95
67	38	37	88	95
66	37	36	85	93
65	36	35	84	92
64	35	34	81	90
63	34	33	79	88
62	33	32	77	86
61	32	31	74	84
60	31	30	71	82
59	30	29	68	79
58	29	28	65	76
57	28	27	61	73
56	27	26	57	69
55	26	25	55	66
54	25	24	52	62

Table 8

CLEP Social Science and History Exam Norms

University of Illinois

ETS Standard Score	Formula Score		Percentile U. of I. LAS (1971) (N = 602)	Approximate Percentile National Norms
	NCT1	NCT2		
659	61	63	96	94
654	60	62	95	93
648	59	61	95	92
643	58	60	93	91
637	57	59	93	89
632	56	58	92	89
627	55	57	91	88
621	54	56	90	87
616	53	55	89	86
610	52	54	88	85
605	51	53	87	84
599	50	52	86	83
594	49	51	84	82
588	48	50	82	80
583	47	49	80	79
577	46	48	78	77
572	45	47	76	76
566	44	46	75	74
561	43	45	72	73
555	42	44	70	72
550	41	43	68	70
544	40	42	65	69
539	39	41	64	68
533	38	40	61	65
528	37	39	58	64

Table 9

CLEP Humanities Exam Norms

University of Illinois

ETS Standard Score	Formula Score		Percentile U. of I. LAS (1971) (N = 308)	Approximate Percentile National Norms
	NCT1	NCT2		
646	59	52	97	93
640	58	51	96	92
637	57	51	95	91
629	56	50	95	90
624	55	49	94	89
619	54	48	93	88
613	53	47	92	87
608	52	46	91	86
602	51	45	90	85
597	50	44	89	83
592	49	44	87	82
586	48	43	83	81
581	47	42	81	80
575	46	41	79	78
570	45	40	76	77
564	44	39	75	74
559	43	39	74	72
554	42	38	73	71
548	41	37	70	69
543	40	36	67	68
537	39	35	66	66
532	38	34	62	65
527	37	33	58	63

Conclusion

The results of the present study indicate that the CLEP Calculus Examination shows definite promise as a P/P examination for beginning calculus courses at the University of Illinois. CLEP Calculus scores did differentiate between students who performed at different grade levels within both Math 120 and Math 135. Both validity and reliability coefficients were quite high. Omitting Math 120 and Math 135 course irrelevant items in the CLEP examination did not further increase validity, i.e., the correlation of CLEP score versus course grade.

The results support the use of the CLEP Calculus Examination for Math 120 proficiency and Math 130 placement. Lack of validity data for higher level courses makes placement and proficiency for higher level mathematics courses rather tenuous.

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